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PALYNOLOGICAL STUDY OF THE VOLHYNIAN DEPOSITS FROM THE CIOFOAIA BROOK (MOLDAVIAN PLATFORM) – PALAEOCLIMATIC AND PALAEOENVIRONMENTAL IMPLICATIONS

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Abstract

The study area is located 10 km east of the city of Fălticeni (Suceava County), in the Preuteşti village. According to Ţibuleac (1998), the age of the deposits from the Ciofoaia brook is Volhynian. 12 samples were collected from the outcrop, out of which 4 were used for palynological investigations. In order to reconstruct the palaeoclimate based on the palynological record, the “Coexistence Approach” (CA) (Mosbrugger and Utescher, 1997) method was applied. Taxa belonging to the *Pinaceae, Taxodiaceae, Fagaceae, Ulmaceae,* and *Juglandaceae* families were identified among the palynomorphs. An abundant dinoflagellate association was observed, especially in sample P321, where the main taxa were assigned to the *Homotryblium* genus.

Keywords: Moldavian Platform, palynology, palaeoclimate, Volhynian, Preuteşti.

Geological setting

The study area belongs to the Moldavian Platform, which represents the western part of the East European Platform. The Moldavian Platform is composed of a crystalline basement and a sedimentary cover. The deposits identified belong to the third stage of sedimentation, comprised between the Upper Badenian and the Maeotian (Ionesi, 1994).

The studied outcrop is located near the city of Fălticeni, in the western part of the Moldavian Platform (fig. 1).

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Fălticeni – Boroaia Formation

According to Ţibuleac (1998), Volhhynian deposits from the Ciofoaia brook represent the eastern limit of the Fălticeni-Boroaia Formation, which is of Volhynian age. The age of this formation was established by Ţibuleac (1998) based on the presence of *Ervilia* div. sp., *Mactra (Podolimactra) eichwaldi* and *Plicatiforma plicata plicata*. The same age was suggested by Ionesi et al. (2005) (fig. 1).

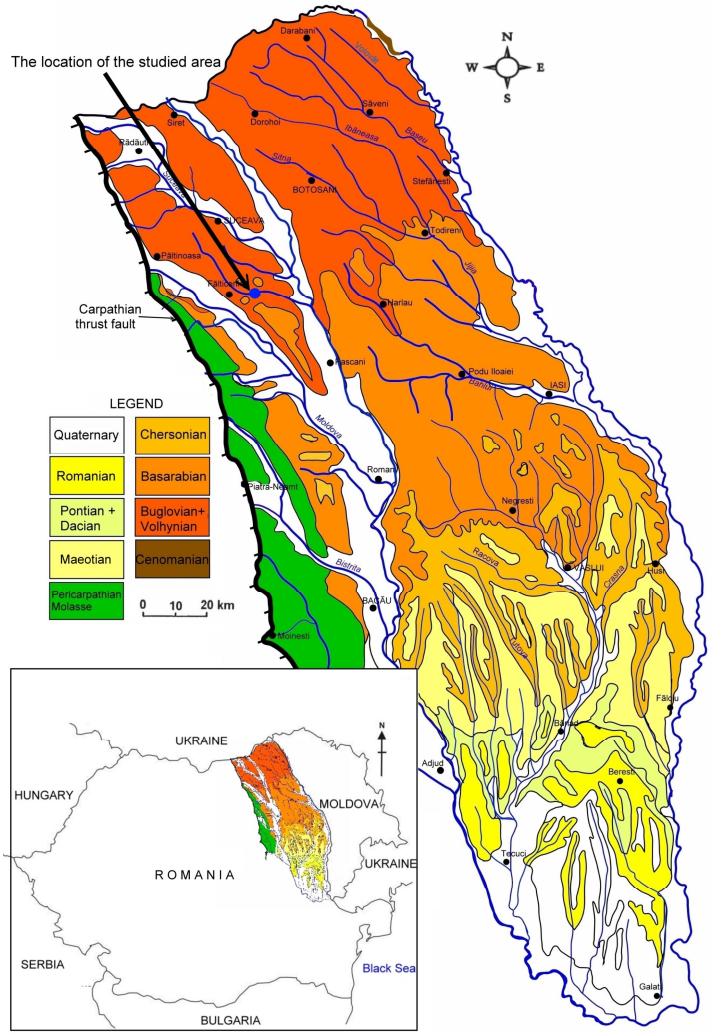

Fig. 1 Geological map of the Moldavian Platform (according to Ionesi et al., 2005).

For the Fălticeni – Sasca – Răuceşti area, Ţibuleac (1998) divided the interval between the Volhynian and the Basarabian into 4 lithological units: the lithological unit of pelites, the lithological unit of pelites and psamites, the Fălticeni-Boroaia Formation and the Valea Moldovei Formation. The present study focuses on deposits from the Fălticeni-Boroaia Formation. Lithologically, this formation consists of marls, clays, sands, sandstones and interbedded tuffs.

From the Fălticeni – Boroaia Formation (Leucuşeşti area) of Upper Volhynian age, Baciu and Ţibuleac (1996) have cited 2 species of charophytae algae (*Nitelopsis* (*Tectochara*) *meriani* (Braun) Grambast & Soulié-Märsche 1972, and *Lychnothamnus barbatus antiquus* Soulié-Märsche, 1989) collected from lacustrine deposits located under the B layer of coal. From the same deposits, Ţibuleac (1998) mentioned the following taxa: *Typha* sp., *Phragmites* sp., *Potamogeton martinianus* Sitar, *Potamogeton* sp., *Pinus* ex. gr. *binae* Beissner, *Pinus* sp., *Glyptostrobus europaeus* (Brognt.) Ung., *Fagus* cf. *atenuata* Goepp., *Carpinus grandis* (Ung.) Heer, *Betula* sp.

The following taxa were also cited from the Fălticeni – Boroaia Formation outcrops (Ţibuleac, 1998, 2001): *Platanus leucophyla* BROGNIART/KNOBLOCH, *Cassiophyllum berenices* UNGER / KRAUSEL, *Sapindus* sp., *Monocotyla* (*Cyperites*) sp., *Corylus avellana* LINNE, *Carya denticulata* (WEBER) ILJINSKAIA, *Acer* cf. *palaeosaccharinum* STUR., *Acer tricuspidatum* BRONN., *Acer* sp., *Carpinus grandis* (UNG.) HEER, *Vitis strictum* (GOEPP.) KN.

This association of taxa (of Upper Volhynian age) reveals an open lake area with low water depth (under 2 m), containing *Characaeae*, *Potamogeton martinianus*, and *Potamogeton* sp. In the proximity of the swamp area, taxa such as *Phragmites* and *Typha* have been located. In the dry area around the swamp, taxa such as *Pinus, Corylus, Carpinus, Fagus* have been described. The author identified palaeotropical taxa (*Platanus leucophylla, Cassiophyllum berenices, Sapindus*) alongside acrotertiary taxa (*Acer tricuspidatum, Carpinus grandis, Carya denticulata* etc.).

A palynological study of the Fălticeni-Boroaia Formation was also conducted by Guşă et al. (1998). The palynological assemblage is represented by 35 taxa. The ratio of the main botanic groups is the following: ferns (18.6 %), angiosperms (41.7 %), and gimnosperms (38.4 %). The palynological assemblage described by the authors is the following: *Monoleiotriletes gracilis, Echinatisporis miocenicus, Polypodiisporites favus, Miricipites rurensis, Inaperturopollenites hiatus, Laevigatosporites haardti, Intratriporopollenites instructus, Pityosporites alatus, Pityosporites labdacus, Araliaceoipollenites edmundi, Polyvestibulopollenites* sp. etc.

In the Râşca area (Fălticeni-Boroaia Formation), Chirilă and Ţabără (2008) identified the following:

- a swamp forest assemblage very close to the coast, where species of *Taxodium, Cyrilla* and *Myrica* were described;
- lacustrine vegetation growing in shallow water, with species such as *Typha, Phragmites* and *Botryococcus*;
- a mixed mesophytic forest well represented in palynological samples, with species such as: *Tilia, Castanea, Betula,* and *Pinaceae* (*Pinus, Abies, Tsuga*).

Acoording to Chirilă and Ţabără (2008), in the Râşca area, the aquatic vegetation (phytoplancton) is divided into autochthonous phytoplankton (*Polysphaeridium zoharyi,*

Lingulodinium machaerophorum, *Operculodinium centrocarpum*, *Botryococcus brauni* and *Spiniferites bentorii*), and allochthonous phytoplancton (*Wetzeliella articulata*, *Deflandrea*, *Cordosphaeridium*), reworked from older deposits.

The Ciofoaia brook outcrop

The geographical coordinates of the studied outcrop are: 47°26'47.2" N, 26°25'06.4" E. 12 samples were collected from the outcrop, out of which 4 were used for palynological investigations (fig. 2). The lithological succession is the following: in the 2 m-thick base, between 297 and 299 m altitude, we have identified a succession of sands with layers of sandstone. In the geological column, between 299 m and 306 m, we have identified "marls with *Cerithium*" and thin layers of coal. We have analyzed 4 palynological samples from this interval, namely P 321 (300.5 m), P 322 (301.5 m), P 323 (302.5 m), and P 324 (303.5 m).

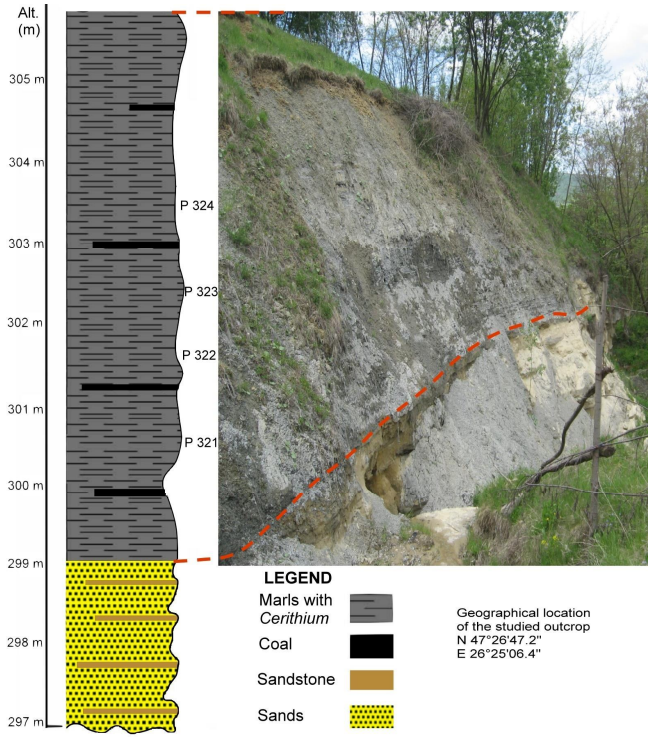

Fig. 2 Lithologic column of the Ciofoaia brook outcrop.

Materials and methods

The palynological study was carried out using 4 samples of grey marls, collected from the interval between 300 and 304 m altitude (fig. 2). The quantity of sediments used for analysis was of approximately 50 g for each sample. Those 50 g were treated with HCl (37%)

in order to remove the carbonates, and, afterwards, with HF (48%) in order to remove the silicate minerals. The separation of palynomorphs from the residue resulted from the chemical reaction described above was made with centrifugal action, using as heavy liquid $ZnCl_2$ with a density 2.00 g/cm^3. The organic fraction resulted was inserted into a mixture of glycerine and gelatine, 1 – 2 drops being mounted on the palynological shim. The visualisation of the palynomophs was carried out with a Leica DM1000 microscope with transmitted light, using amplifications of X100, X400.

Palynological assemblage

Out of the analyzed samples, we observed a higher taxonomic content in sample P321. The percentage of organic matter in this sample is 15% (according to the Shvetsov diagram, 1954; in Sittler and Schuler, 1991).

Table 1. Palynological assemblage identified in samples from the Ciofoaia brook

	P321	**P322**	**P323**	**P324**
Phytoplancton				
Homotryblium sp.	++			
Tythodiscus sp.	x		x	x
Spiniferites ramosus (EHRENBERG 1838) LOEBLICH et LOEBLICH 1966	x			
Operculodinium centrocarpum (DEFLANDRE et COOKSON 1955) WALL 1967	x	x		
Polysphaeridium sp.		x		
Lingulodinium machaerophorum (DEFLANDRE et COOKSON 1955) WALL 1967		x		
Systematophora cf. *placacantha* (DEFLANDRE et COOKSON 1955) DAVEY, DOWNIE, SARJEANT et WILLIAMS 1969			x	
Lingulodinium polyedrum (DEFLANDRE et COOKSON 1955) WALL 1967			x	
Botryococcus braunii KÜTZING 1849				x
Wetzeliella sp. (reworked)	x			
Pteridophyta				
Laevigatosporites haardti (POT. et VEN. 1934) TH. et PF. 1953 subsp. *haardti* KRUTZSCH 1967	x	x	x	x
Polypodiaceoisporites gracillimus NAGY 1963	x			
Leiotriletes wolffi wolffi KRUTZSCH 1962		x		
Leiotriletes sp.		x	x	
Neogenisporis neogenicus KRUTZSCH 1962				x
Baculatisporites quintus quintus THOMSON – PFLUG 1953				x
Hydrosporis sp.	x			
Gymnospermatophyta				
Inaperturopollenites hiatus (POTONIÉ 1931) THOMSON et PFLUG 1953	x	x	x	x
Inaperturopollenites concedipites (WODEHOUSE 1933) KRUTZSCH 1971	+	x		x
Inaperturopollenites sp.	++	x	x	x
Pityosporites labdacus (POTONIÉ 1931) THOMSON et PFLUG 1953	x	x	x	

	P321	P322	P323	P324
Pityosporites microalatus (POTONIÉ 1931) THOMSON et PFLUG 1953	x	x	x	x
Pityosporites scopulipites (WODEHOUSE 1933) KRUTZSCH 1971	x	x		
Pityosporites alatus (POTONIÉ 1931) THOMSON et PFLUG 1953	x	x		
Pityosporites insignis (NAUMOVA ex BOLCHOVITINA 1953) KRUTZSCH 1971	x			x
Pityosporites minutus (ZAKLINSKAJA 1957) KRUTZSCH 1971		x	x	x
Pityosporites cedrisacciformis KRUTZSCH 1971	x			
Pinuspollenites miocaenicus NAGY 1985	x	x		
Pityosporites sp.	++	+	x	x
Abiespollenites sp.	x	x	x	x
Abiespollenites latisaccatus (TREVISAN 1967) KRUTZSCH 1971	x			x
Podocarpidites sp.	x			
Podocarpidites libellus (POTONIÉ 1931) KRUTZSCH 1971	x			
Piceapollis tobolicus (PANOVA 1966) KRUTZSCH 1971	x	x		
Piceapollis sp.		x		
Zonalapollenites sp.	x			x
Zonalapollenites minimus KRUTZSCH 1971	x			
Zonalapollenites verrucatus KRUTZSCH 1971	x			
Zonalapollenites rueterbergensis KRUTZSCH 1971			x	
Ginkgo sp.	x		x	
Cedripites sp.	x			
Sciadopityspollenites sp.			x	x
Angiospermatophyta. Monocotyledonatae				
Monocolpopollenites sp.	x			
Typha sp.		x		
Graminidites media (COOKSON 1947) POTONIÉ 1960			x	
Angiospermatophyta. Dicotyledonatae				
Quercopollenites sp.	x	x	x	
Quercopollenites granulatus NAGY 1969	x			
Quercopollenites petrea NAGY 1969	x		x	
Quercopollenites robur NAGY 1969	x			
Tricolporopollenites asper (THOMSON et PFLUG 1953) KRUTZSCH 1960			x	
Tricolporopollenites henrici (POTONIÉ 1931) KRUTZSCH 1960	x	x	x	
Tricolporopollenites microhenrici (POTONIÉ 1930) KRUTZSCH 1960	x	x	x	x
Ilexpollenites iliacus (POTONIE 1931) POTONIE 1960	x			x
Faguspollenites minor NAGY 1969	x			
Aceripollenites rotundus NAGY 1969	x			x
Aceripollenites sp.	x		x	
Myricipites sp.	x			
Myricipites bituitus (POTONIE 1931) NAGY 1969	x		x	
Ulmipollenites sp.	x			
Zelkovaepollenites thiergarti NAGY 1969	x			
Caryapollenites simplex (POTONIÉ 1931) KRUTZSCH 1960	x		x	x
Engelhardtioidites microcoryphaeus (POTONIÉ 1931) THOMSON et THIERGART ex POTONIÉ 1960	x	x	x	x

	P321	P322	P323	P324
Momipites punctatus (POTONIÉ 1931) NAGY 1969	x		x	x
Pterocaryapollenites stellatus (POTONIÉ 1931) THIERGART 1937	x			
Corylus sp.	x			
Alnipollenites verus (POTONIÉ 1931) POTONIÉ 1934	x		x	
Chenopodipollis multiplex (WEYLAND et PFLUG 1957) KRUTZSCH 1966	++	x		x
Betulaepollenites sp.	x			
Intratriporopollenites sp.	x	x		
Sapotaceoidaepollenites sp.	x			
Tricolpopollenites liblarensis (THOMSON 1950) THOMSON et PFLUG 1953 subsp. *liblarensis*	x			
Liquidambarpollenites sp.	x			
Carpinipites carpinoides (PFLUG 1953) NAGY 1985	x	x		
Araliaceoipollenites edmundi (POTONIE 1931) POTONIE 1951	x			
Cyrillaceaepollenites exactus (POTONIÉ 1931) POTONIÉ 1960	x		x	
Tricolporopollenites cingulum (POTONIE 1931) THOMSON et PFLUG 1953 subsp. *oviformis* (POTONIE 1931) THOMSON et PFLUG 1953	x		x	
Ericipites sp.	x			x
Platycaryapollenites sp.			x	
Magnolipollis sp.	x			

LEGEND: x very rare (1-2 grains) , + rare (3-9 grains), ++ frequent (more than 10 grains)

Based on this study, we have divided the palynological taxa identified in the Ciofoaia brook outcrop into marine and continental assemblages.

Marine assemblage (marine domain). During the present study, we have found many dinoflagellates in the samples from the Ciofoaia brook outcrop: *Homotryblium* sp., *Tythodiscus* sp., *Spiniferites ramosus*, *Operculodinium centrocarpum*, *Polysphaeridium* sp., *Lingulodinium machaerophorum*, *Systematophora* cf. *placacantha*, *Lingulodinium polyedrum*, *Botryococcus braunii*, *Wetzeliella* sp. (reworked).

The shelf zone is the source area for dinoflagellates, with a higher percentage in sample P 321 (300.5 m). As can be seen in figure 3, it is a proximal shelf area (inner neritic – outer neritic), with low water depth, where we have found *Spiniferite* and *Operculodinium* taxa. In the inner neritic area, species such as *Homotryblium* are also present. Such species have also been reported in the area near the shore, which has reduced salinity (Dybkjær, 2004). In another study (Sluijs et al., 2005), representatives of this genus have been interpreted as characteristic for high salinity or lagoonal settings.

A similar dinoflagellate assemblage was presented by Chirilă and Ţabără (2008) for the outcrop from the Ţiganca brook, located approx. 20 km west of the Ciofoaia brook. Both outcrops belong to the same stratigraphic unit: the Fălticeni-Boroaia Formation (Ţibuleac, 1998). The sedimentation environment is near the coast, a fact accentuated by a higher percentage of spores and pollen (continental organisms), as well as the predomination of terrigenous organic matter.

Palaeoecological interpretation based on dinocyst association:

Lingulodinium machaerophorum (tropical species) can be considered a temperate to tropical, coastal euryhaline species present in regions with a summer sea-surface temperature (SST) exceeding 12^0C (Marret and Zonneveld, 2003). It is distributed within a very broad salinity range and has been recorded in environments ranging from brackish to marine, with salinities between 16.9 and $36.7^0/_{00}$.

Operculodinium centrocarpum is generally reported as a cosmopolitan species that might have low relative abundances in the tropical area, and high relative abundances in regions with cold/temperate waters, such as the North Atlantic (Wall et al., 1977, Marret and Zonneveld, 2003). This species is distributed within a very broad range: temperature (-2.1^0C and 29.6^0C) and salinity ($16.1 – 36.8^0/_{00}$).

Homotryblium sp. is frequent in sample P321. This taxon is characteristic for marginal environments or lagoonal settings (Dale, 1996, Sluijs et al., 2005). *Homotryblium* has been cited in Denmark by Dybkjær (2004), being characteristic for the low salinity environment from Oligocene – Lower Miocene deposits.

Spiniferites ramosus is present in a low percentage in the palynological assemblage identified in the samples from the Ciofoaia brook. This taxon is an indicator for outer neritic settings, together with *Lingulodinium* div. sp., *Operculodinium centrocarpum* and *Systematophora* cf. *placacantha* (fig. 3).

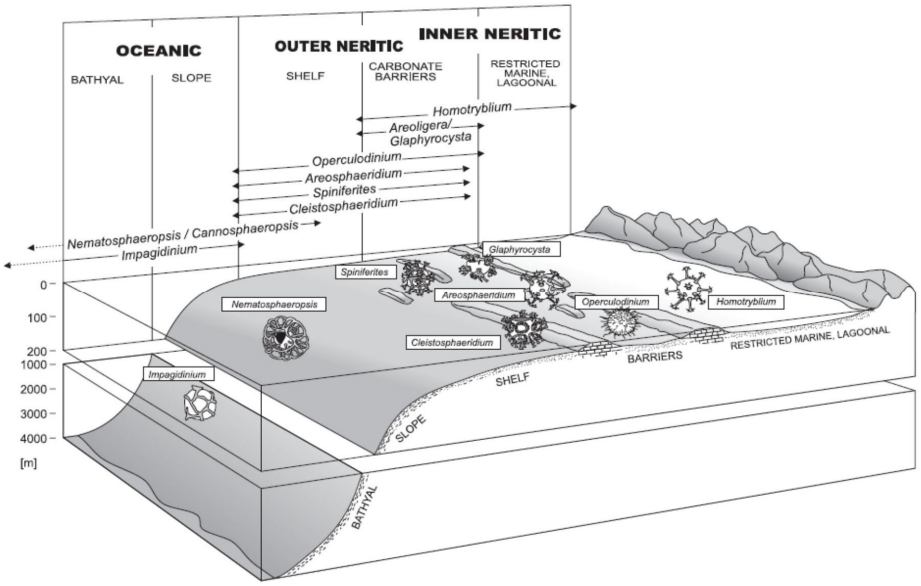

Fig. 3 Schematic model for the distribution of dinocyst associations along a proximal–distal transection of the sedimentary basin (after Brinkhuis, 1994; modified by Sluijs et al., 2005).

Continental assemblage (continental domain). Based on the continental palynomorphs, we have separated the following paleobiocenosis: a swamp assemblage, a

riparian assemblage, a mixed mesophytic forest, and a middle and high altitude forest (fig. 4).

The swamp assemblage is represented by aquatic plants such as *Typha*, and green algae such as *Botryococcus*, which indicate the presence of freshwater in the depositional environment. Furthermore, we have identified *Taxodium*, *Glyptostrobus* and various ferns existing in the same area, which was periodically flooded. The swamp forests produced great quantities of organic matter, which, while accumulating in the boggy ground, were subjected to peat-forming processes. According to Worobiec (2009), these swamp forests were widespread in Europe during the period covering the Oligocene to the Pliocene. In the Polish lowland, they had most favourable conditions in the Early and Middle Miocene.

The riparian assemblage is well represented by taxa such as *Engelhardtia, Myrica, Cyrilla, Ulmus, Zelkova* and *Alnus*. From the mixed mesophytic forest, we have taxa such as *Quercus, Fagus, Ilex, Carya, Acer, Pterocarya, Carpinus*. The middle and high altitude forest is well represented by pinaceae. Among the conifers, *Pinus*, *Picea* and *Abies* played a considerable role.

Terrestrial herbs consist of seven taxa, represented mainly by ground-covering vegetation in the mesophytic forest. *Chenopodiaceae* are the dominant groups in this assemblage.

Palynofacies analysis

According to the Shvetsov diagram (1954, in Sittler and Schuler, 1991), the organic matter preserved in the samples that have been quantitatively analyzed has values ranging between 10 and 30%. A higher percentage of organic matter was observed in P323 (approx. 30%). In this sample, the main components are small phytoclasts, black coal remains, and yellow-brown fragments of tissue and cuticle. Amorphous Organic Matter (AOM) represents a maximum of 5% of the total kerogen content. The Thermal Alteration Index (TAI) established on the continental palynomorphs is between -2 and 2. The kerogen determined based on optical criteria is type III. It can be concluded, thus, that the kerogen analyzed from the Volhynian deposits of the Fălticeni-Boroaia Formation is in an immature stage of hydrocarbon generation.

Palaeoclimatical interpretation

The results of pollen analysis were used to reconstruct the main types of Sarmatian plant communities. The recent vegetation picture has the form of a mosaic, in which the arrangement of the elements depends on environmental and climatic conditions. Knowledge about the requirements of the nearest living relatives is necessary in order to draw conclusions about the requirements of fossil plants and about the structure of the ancient vegetation.

In order to reconstruct the paleoclimate based on the palynological record, the „Coexistence Approach" (CA) (Mosbrugger and Utescher, 1997) method was applied. This method has frequently been used for the reconstruction of the European tertiary paleoclimate.

In the present study, we have calculated 4 paleoclimatic parameters: Mean annual temperature (MAT), Mean annual precipitation (MAP), Mean annual temperature of the warmest month (WMT), Mean annual temperature of the coldest month (CMT).

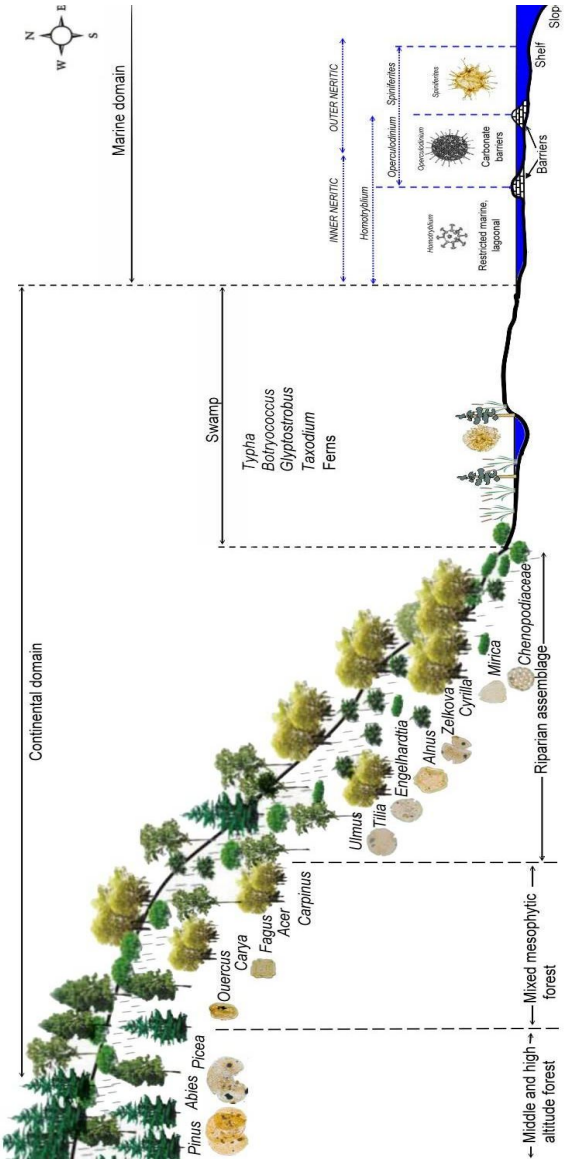

Fig. 4 Graphical representation of the continental and marine domain for the analyzed samples from the Ciofoaia brook.

Estimations of MAT and MAP have been obtained on 38 palynological taxa identified in 4 of the samples from the Ciofoaia brook outcrop.

The values calculated by us using the "Coexistence Approach" method are the following (fig. 5): MAT 15.7 – 16.7°C, MAP 1300 – 1355 mm/yr, WMT 21.7 – 27.8°C, and CMT -0.3 – 7°C. The upper and lower limits for the climatic parameters above are listed in table 2. The lower limit for MAT (15.7°C) is given by *Araliaceoipollenites edmundi*, and the upper limit (16.7°C) is marked by *Sciadopityspollenites* sp. For MAP, the lower limit (1300 mm/yr) is also provided by *Sciadopityspollenites* sp., and the upper limit (1355 mm/yr) belongs to *Carpinipites carpinoides*. The lower limit for WMT (21.7°C) is given by *Pterocaryapollenites stellatus*, while the upper limit (27.8°C) is attributed to *Sciadopityspollenites* sp. For the CMT, the lower limit (-0.3°C) belong to *Cedripites* sp., and the upper limit (7°C) is given by *Sciadopityspollenites* sp. Thus, the *Sciadopityspollenites* sp. taxa are important elements in palaeoclimatic interpretation.

Table 2. Climate parameters for the flora from the Ciofoaia brook, derived from the microfloristic record. The taxa responsible for the minimum and maximum values are listed

Climate parameter	Min	Max	Left border set by	Right border set by
MAT	15.7°C	16.7°C	*Araliaceoipollenites edmundi*	*Sciadopityspollenites* sp.
MAP	1300 mm/yr	1355 mm/yr	*Sciadopityspollenites* sp.	*Carpinipites carpinoides*
WMT	21.7°C	27.8°C	*Pterocaryapollenites stellatus*	*Sciadopityspollenites* sp.
CMT	-0.3°C	7°C	*Cedripites* sp.	*Sciadopityspollenites* sp.

The palaeoclimatic parameters calculated by us (Fig. 5) are similar to those calculated for the Ţiganca brook outcrop by Chirilă & Ţabără (2008) (Table 3): MAT between 15.3 – 16.6°C, and MAP 1300 – 1355 mm/year. This is understandable, given the fact that the outcrop from the Ciofoaia brook is located 20 km east of the Ţiganca brook outcrop, and the fact that they both belong to the Fălticeni-Boroaia Formation.

Table 3. Climate parameters studied from the outcrops of the Ciofoaia and Ţiganca brooks, derived from the microfloristic record.

Climate parameter	Min	Max	Assemblage
MAT	15.7°C	16.7°C	Ciofoaia brook assemblage
MAP	1300 mm/yr	1355 mm/yr	(the present paper)
MAT	15.3°C	16.6°C	Ţiganca brook assemblage
MAP	1300 mm/yr	1355 mm/yr	(according to Chirilă and Ţabără, 2008)

This type of assemblage present in the outcrops from the Ţiganca and Ciofoaia brooks was not identified in any other outcrop from the Moldavian Platform that has been studied. Therefore, the outcrop from the Ciofoaia brook represents the easternmost part of the Fălticeni-Boroaia Formation.

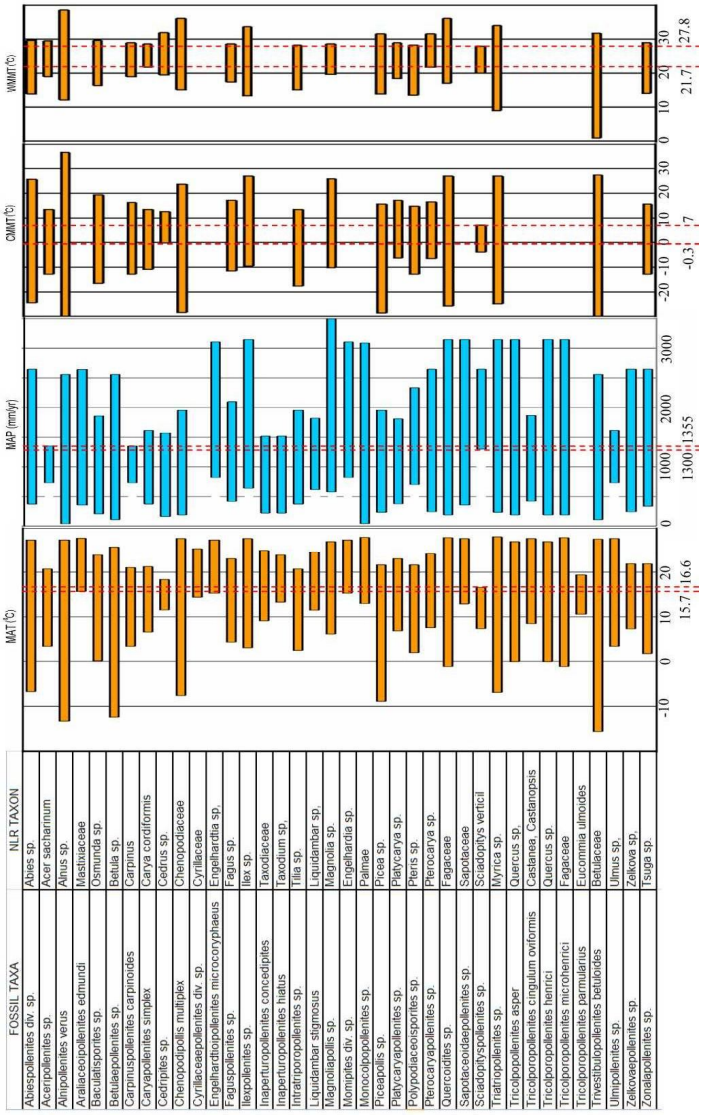

Fig. 5 Estimation of the MAT, MAP, CMT, and WMT values using the "Coexistence Approach" method.

Conclusions

In the present study, based on the palynological assemblage, we have separated the following biocenosis for continental palynomophs: a swamp assemblage, a mixed mesophytic forest and a riparian assemblage. The marine assemblage is represented by: *Homotryblium* sp., *Tytthodiscus* sp., *Spiniferites ramosus*, *Operculodinium centrocarpum*, *Polysphaeridium* sp., *Lingulodinium machaerophorum*, *Systematophora* cf. *placacantha*, *Lingulodinium polyedrum* and *Botryococcus braunii*. In the Moldavian Platform, these taxa have been found only in the outcrop from the Țiganca brook, belonging to the Fălticeni-Boroaia Formation. The similarity between these two assemblages (from the Ciofoaia and the Țiganca brooks, respectively) confirms the fact that the studied outcrop belongs to the Fălticeni-Boroaia Formation.

The Thermal Alteration Index (TAI) established on the continental palynomorphs is between -2 and 2, while the kerogen determined based on optical criteria is type III. Based on these two elements, we can conclude that the kerogen analyzed from these deposits is in an immature stage of hydrocarbon generation.

The values calculated by us, using the "Coexistence Approach" method are the following (fig. 5): MAT 15.7 – 16.7°C, MAP 1300 – 1355 mm/yr, WMT 21.7 – 27.8°C, and CMT -0.3 – 7°C.

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CAPTION OF PLATES

Plate I

1. *Homotryblium* sp. (transmitted white light)
2. *Idem*, incident blue light (fluorescence)
3-4. *Homotryblium* sp.
5. *Tytthodiscus* sp.
6. *Operculodinium centrocarpum* (DEFLANDRE et COOKSON 1955) WALL 1967
7. *Spiniferites ramosus* (EHRENBERG 1838) LOEBLICH et LOEBLICH 1966
8. *Lingulodinium machaerophorum* (DEFLANDRE et COOKSON 1955) WALL 1967
9. *Lingulodinium polyedrum* (DEFLANDRE et COOKSON 1955) WALL 1967
10. *Systematophora* cf. *placacantha* (DEFLANDRE et COOKSON 1955) DAVEY, DOWNIE, SARJEANT et WILLIAMS 1969
11. *Hyphae* (fungus)
12. *Hydrosporis* sp.

Plate II

1. *Laevigatosporites haardti* (POT. et VEN. 1934) TH. et PF. 1953 subsp. *haardti* KRUTZSCH 1967
2. *Polypodiaceoisporites gracillimus* NAGY 1963
3. *Leiotriletes wolffi wolffi* KRUTZSCH 1962
4. *Baculatisporites quintus quintus* THOMSON – PFLUG 1953
5. *Neogenisporis neogenicus* KRUTZSCH 1962
6. *Stereisporites (Distverrusporis) electoides electoides* KRUTZSCH 1963
7. *Inaperturopollenites concedipites* (WODEHOUSE 1933) KRUTZSCH 1971
8. *Inaperturopollenites hiatus* (POTONIÉ 1931) THOMSON et PFLUG 1953
9. *Sciadopityspollenites* sp.
10. *Pityosporites labdacus* (POTONIÉ 1931) THOMSON et PFLUG 1953
11. *Idem*, incident blue light (fluorescence)
12. *Pityosporites microalatus* (POTONIÉ 1931) THOMSON et PFLUG 1953
13. *Pityosporites labdacus* (POTONIÉ 1931) THOMSON et PFLUG 1953
14. *Piceapollis tobolicus* (PANOVA 1966) KRUTZSCH 1971
15. *Ginkgo* sp.
16. *Podocarpidites* sp.
17. *Pityosporites scopulipites* (WODEHOUSE 1933) KRUTZSCH 1971
18. *Zonalapollenites minimus* KRUTZSCH 1971

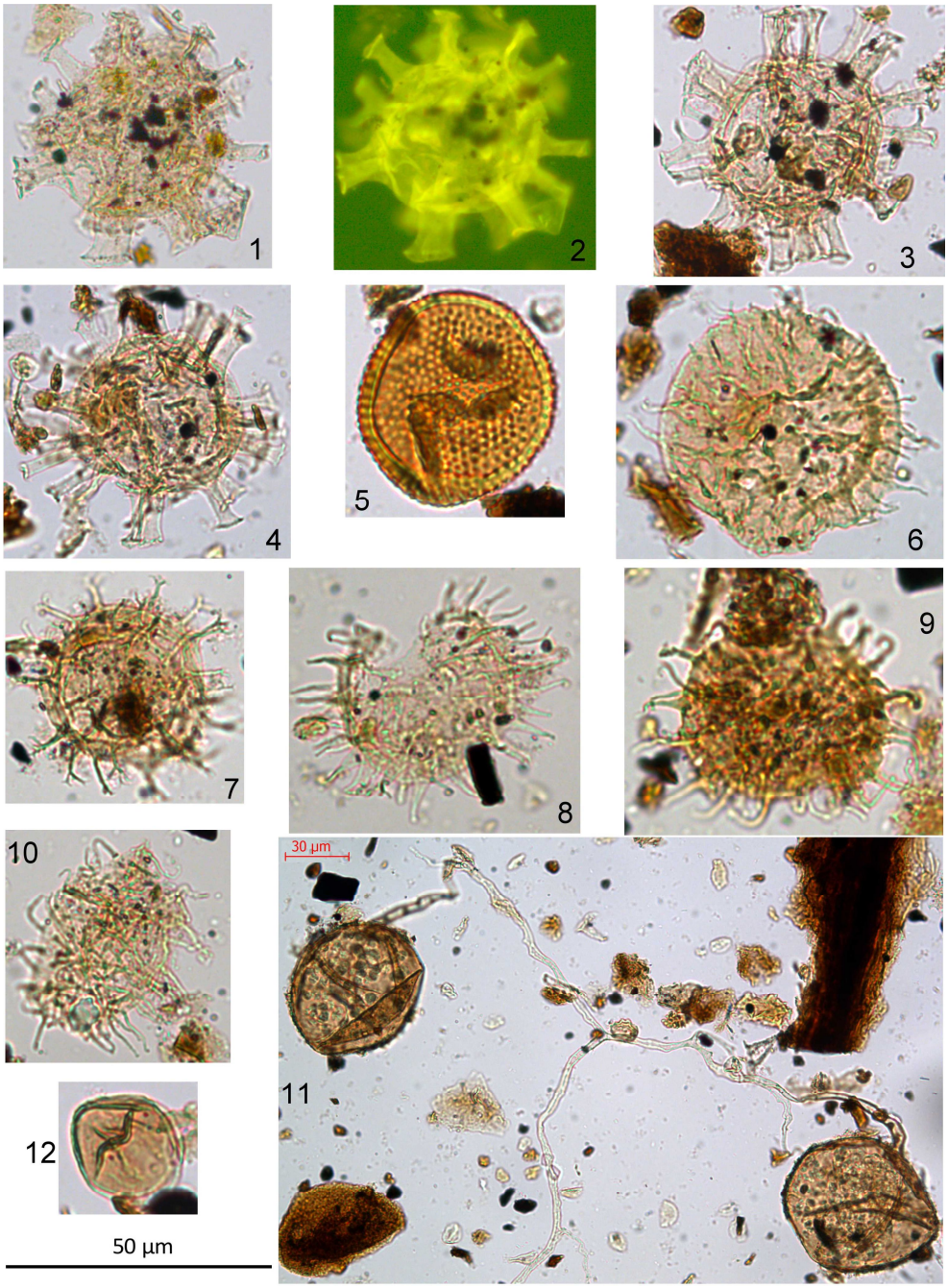
Plate III

1. *Abiespollenites latisaccatus* (TREVISAN 1967) KRUTZSCH 1971
2. *Pityosporites alatus* (POTONIÉ 1931) THOMSON et PFLUG 1953
3. *Pityosporites insignis* (NAUMOVA ex BOLCHOVITINA 1953) KRUTZSCH 1971
4. *Podocarpidites libellus* (POTONIÉ 1931) KRUTZSCH 1971
5. *Aceripollenites rotundus* NAGY 1969

6. *Chenopodipollis multiplex* (WEYLAND et PFLUG 1957) KRUTZSCH 1966
7. *Caryapollenites simplex* (POTONIÉ 1931) KRUTZSCH 1960
8. *Tricolporopollenites cingulum* (POTONIE 1931) THOMSON et PFLUG 1953 subsp. *oviformis* (POTONIE 1931) THOMSON et PFLUG 1953
9. *Corylus* sp.
10. *Faguspollenites minor* NAGY 1969
11. *Magnolipollis* sp.
12. *Cyrillaceaepollenites exactus* (POTONIÉ 1931) POTONIÉ 1960
13. *Alnipollenites verus* (POTONIÉ 1931) POTONIÉ 1934
14. *Carpinipites carpinoides* (PFLUG 1953) NAGY 1985
15. *Tricolporopollenites microhenrici* (POTONIÉ 1930) KRUTZSCH 1960
16. *Quercopollenites petrea* NAGY 1969
17. *Quercopollenites granulatus* NAGY 1969
18. *Quercopollenites robur* NAGY 1969
19. *Tricolporopollenites henrici* (POTONIÉ 1931) KRUTZSCH 1960
20. *Liquidambarpollenites* sp.
21. *Araliaceoipollenites edmundi* (POTONIE 1931) POTONIE 1951
22. *Tricolpopollenites liblarensis* (THOMSON 1950) THOMSON et PFLUG 1953 subsp. *liblarensis*
23. *Betulaepollenites* sp.
24. *Myricipites bituitus* (POTONIE 1931) NAGY 1969
25. *Ilexpollenites iliacus* (POTONIE 1931) POTONIE 1960
26. *Zelkovaepollenites thiergarti* NAGY 1969
27. *Ericipites* sp.
28. *Graminidites media* (COOKSON 1947) POTONIÉ 1960

Plate IV

1 – 3. Organic matter extracted from P321. The palynofacies includes black coal phytoclasts (PHY), palynomorphs (PAL), brown-yellow fragments (BYF), amber (AMB), dinoflagellates (DIN).
3. Organic matter under transmitted light.
4. *Idem fig. 3* (under incident blue light - fluorescence).
5, 6. Organic matter included in P323. Small black coal phytoclasts and brown-yellow fragments are predominant.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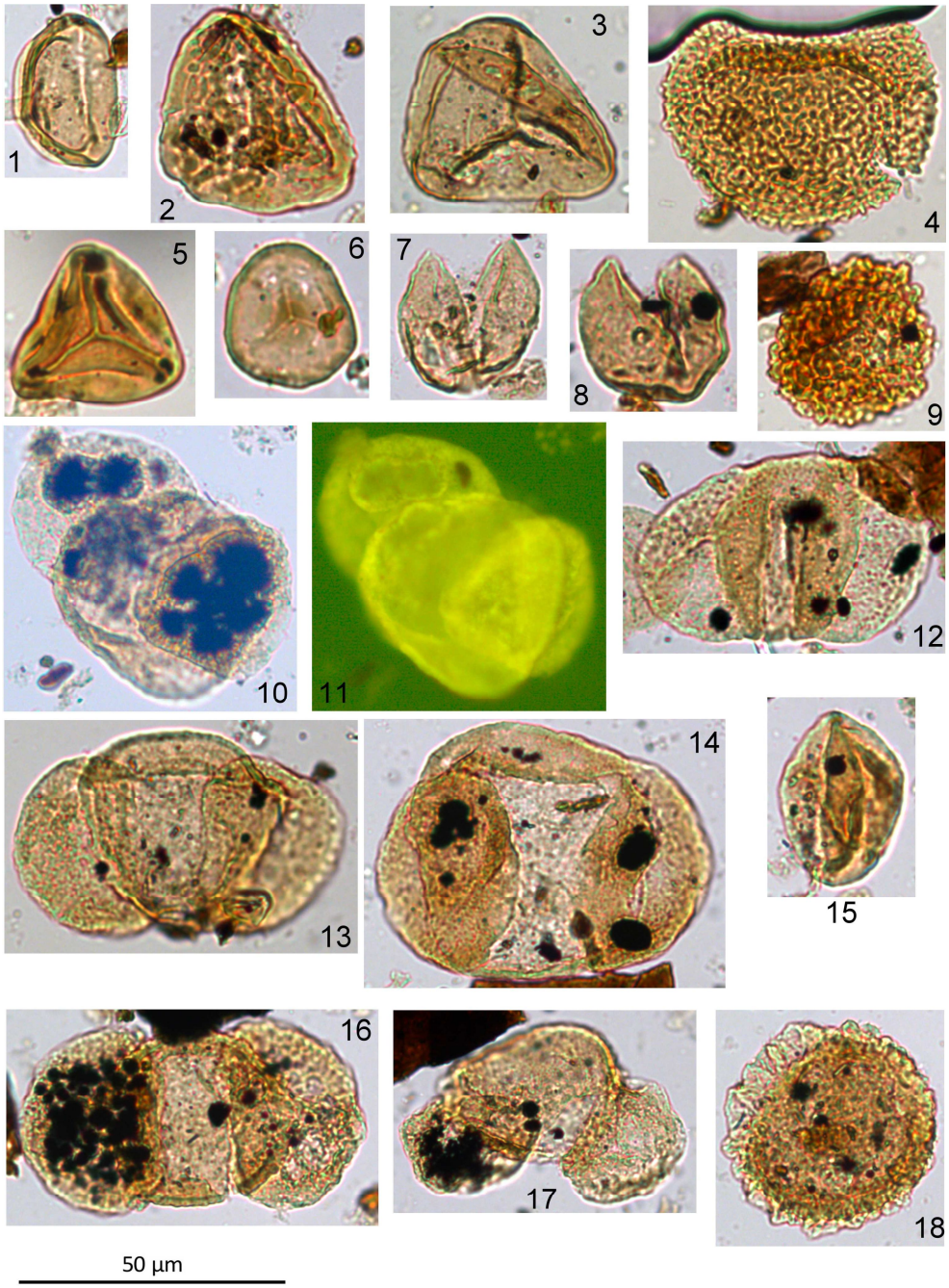
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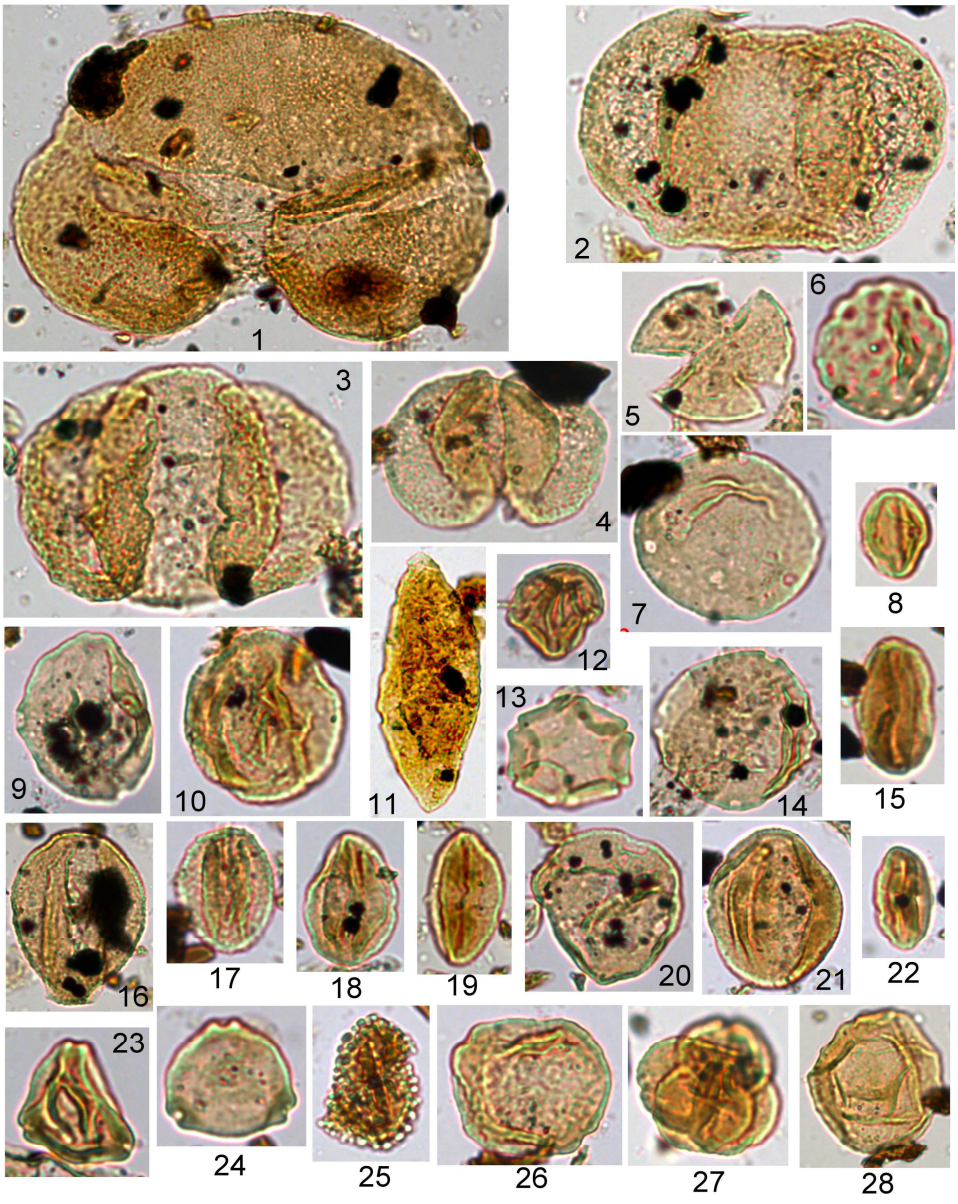
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